

REVIEW OF SUPER Ni/Cd CELL DESIGNS AND PERFORMANCE

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ABSTRACT

Eagle-Picher Industries, Inc., in cooperation with Hughes Aircraft Company, began production of the Super Nickel-Cadmium cell in 1989. Since that time the Super Nickel-Cadmium cell has been deployed in a wide variety of satellites. This paper will review one of those programs and provide a performance update. We will discuss storage requirements and capacity histories for the various Super NiCad Cell designs.

INTRODUCTION

The Super NiCad was first introduced in 1989 by Hughes Aircraft Company for use in the LESAT satellite. The cell is manufactured at Eagle-Picher Industries in Colorado Springs, Colorado. The Super NiCad differs from standard nickel cadmium cells in several ways:

1. The positive plate is made by an electrochemical-chemical deposition process. This process is based on the Air Force patented buffered deposition process.
2. The positive plate loading target is in the range of 1.65 g/cc void. This is lower than the standard NiCad positive loading which is in the range of 2.0 g/cc void.
3. The negative electrode in the Super NiCad has similar loading levels to the standard NiCad but is produced by an aqueous electrochemical chemical deposition method.
4. The negative to positive ratio is much higher in the Super NiCad normally exceeding a theoretical negative to positive of 1.8. This allows for precharge in the range of 40% of excess negative capacity.
5. Finally, the Super NiCad incorporates an impregnated zirconia separator. This separator is as wettable as the nylon used in standard NiCads, however it is much more resistant to the alkaline environment.

Because of the unique design there are some special storage considerations with Super NiCad:

1. Unlike the standard NiCad, the Super NiCad should never be stored under short-circuit.
2. The Super NiCad is best stored under trickle charge.
3. When constant charging during storage is impractical, the Super NiCad can be periodically "topped-off."

4. When any type of charging is impractical, the Super NiCad is best stored open-circuited and completely discharged at low temperature.

The Super NiCad was developed to correct observed failure mechanisms of the standard nickel cadmium cells. It was anticipated that the changes discussed above would provide some performance advantages:

1. The deposition method and loading limits were to provide better active material utilization, better ability to withstand deep discharge and less plate expansion over cycle life.
2. The negative manufacturing process was designed to improve active material utilization and decrease plate deterioration, thereby minimizing cadmium migration.
3. The higher precharge had better gas management as its goal, additionally there was the expected benefit of better overcharge protection.
4. The zirconia separator was chosen in order to avoid the oxidation to carbonate that was seen with the nylon separator.

The purpose of this paper is to explore functioning Super NiCad programs and determine how well the cells have met performance goals. Specific data will be drawn from the SMEX 9 AH program. We will first look at the beginning of life (BOL) performance characteristics. Next we will discuss cell performance during accelerated life cycle testing. Finally, we will briefly discuss cell performance in flight.

ACCEPTANCE AND STRESS TESTING

Beginning of Life

All Super NiCad cells that are destined for flight or accelerated life cycling are sent through an acceptance test regime (see Figure 1). The test is based on the NASA approved flight cell acceptance test. It involves testing at 0° C, 10° C and 22° C. Charge currents are varied from trickle charge (C/20) to rapid charge (C/2). The cells are normally discharged at a C/2 current, but there are tests to demonstrate charge retention (self-discharge rate) and high current discharge performance (at 5C). In addition to the electrical testing, representative plates are subjected to a destructive stress test (see Figure 2).

Since the normal satellite operating temperature is around 10° C, all capacity qualification testing is performed at this temperature. The Super NiCads have demonstrated from 85 to 95% utilization at this early stage of cell life.

ACCEPTANCE TESTING PROCEDURE

Capacity Test at 10° C

- Cells are shorted down to 0.010 volt maximum, 16 hour stand.
- Cells are soaked at 10° C for 4 hours.
- C/10 charge for 20 hours, 1 hour open-circuit stand, C/2 discharge to 1.0 volt.

Overcharge and Capacity Test at 0° C

- Cells are shorted down to 0.010 volt maximum, 12 hour minimum.
- Cells are soaked at 0° C for 4 hours.
- C/20 charge for 72 hours, 1 hour open-circuit stand, C/2 discharge to 1.0 volt.

High Current Discharge Test at 22° C

- Cells are shorted down to 0.010 volt maximum, 12 hours minimum.
- Cells are soaked at 22° C for 4 hours.
- C/10 charge for 20 hours, 5C pulse discharge for 10 seconds, C/2 discharge to 1.0 volt.

Charge Retention (Discharged) Test at 22° C

- Cells are shorted down for 12 hours.
- C/10 charge for 10 minutes, open-circuit for 24 hours, minimum voltage 1.15 volts.

Figure 1. Description of EPI Acceptance Test.

EPI POSITIVE ELECTRODE STRESS TEST

- Hot Formation: 5C rate, 70° C, 20% KOH, 2 cycles.
- Pre-Stress: Weight, thickness and visual appearance characterization.
- Initial Capacity: Charge at 5C for 12 min., C/2 for 1 hour. Discharge at C rate to 1.0 V vs. Ni sheet.
- 200 Cycles: Charge at 10C for 12 minutes. Discharge at 10C for 8 min. Diode clamped to -1.0 V.
- Ending Capacity: 5 Cycles, same as initial capacity.
- Visual appearance.
- Scrub, rinse, and dry.
- Weight loss and swelling.

Figure 2. Stress Test Regime.

After 200 stress cycles (charge and discharge at 10°C) the plates show less than 3% thickness growth and no blistering. By comparison, electrodes for standard NiCads seldom survive the stress test intact.

Cell voltages at 0°C do not exceed 1.50 volts on overcharge at C/20 (see Figure 3).

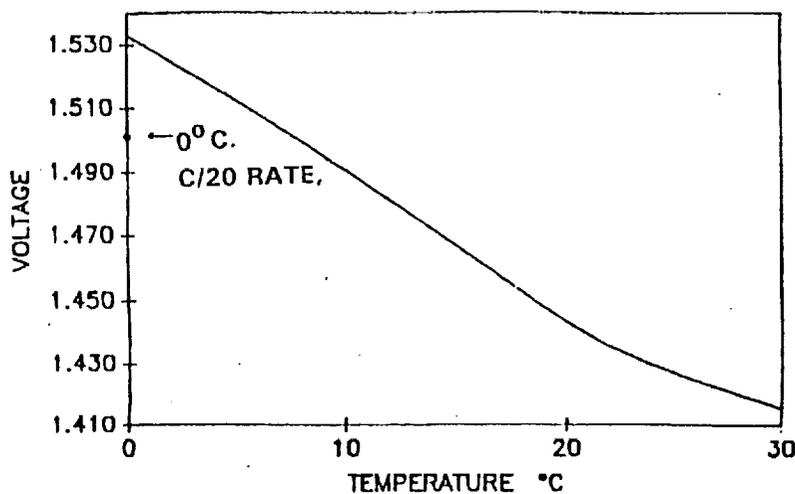


Figure 3. Typical Super NiCad End-of-Charge Voltage vs. Temperature, C/10 Rate.

Typically all cells of a given lot perform within a 20 millivolt range.

Figure 4 depicts average cell performance values for the SMEX acceptance test.

SMEX AVERAGE ACCEPTANCE TEST RESULTS		
	0°C Test	10°C Test
Average Capacity	11.55 AH	11.76 AH
Average EOC Voltage	1.491	1.4824
Average EOC Pressure	2.5 psi	11.4 psi
Average Final Voltage after 10 Second 5C Discharge: 1.1429 V		

Figure 4. Results of SMEX acceptance testing.

ACCELERATED LIFE CYCLING

The super NiCad has been tested in both simulated LEO and GEO orbits and has passed all NASA requirements to date.

FLIGHT PERFORMANCE

The super NiCad has demonstrated end-of-charge voltages in the ranges of 1.40 to 1.48 and end-of-discharge voltages in the ranges of 1.18 to 1.21. These end-of-charge voltages are approximately 20 millivolts lower than those seen in standard nickel cadmium cells and the discharge voltages are similarly higher than those seen in standard nickel cadmium cells.

Initial flight data for the SMEX program agree with the trends that were suggested by the accelerated testing.

CONCLUSION

Beginning-of-life test data show increased active material utilization in the super NiCad design, as anticipated. Cell voltages and pressures are well within acceptable limits. Stress testing indicates that the Super NiCad positive has a longer theoretical life than the standard Nickel cadmium positive.

Accelerated life cycling has provided a positive picture of the long term Super NiCad performance. Super NiCad cells have surpassed the life normally expected in a standard NiCad. All super NiCads currently in flight are performing well and within all specified limits.

